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WIND ENERGY SCIENCE DISCUSSIONS
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Interactive comment on "Ground-generation airborne wind energy design space exploration" *by* Markus Sommerfeld et al.

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Response to referee 3 wes-2020-123

Markus Sommerfeld

December 31, 2021

1 Author response

Dear reviewer 3,
Thank you very much for your helpful comments to our manuscript, “Ground-generation airborne wind energy design space exploration”, wes-2020-123. I am very sorry that I could not resubmit the revision sooner. My full-time work and family, together with a relocation to Japan, required my attention and time.
The manuscript underwent major revision. Several figures and sections have been replaced and new ones have been added.
Sincerely, Markus Sommerfeld

2 General Comments

Are clear objectives and/or hypotheses put forward? This can clearly be improved. In the introduction, the authors can better highlight what the main hypothesis is (one paragraph) and what the contributions of this paper are (one paragraph).

- Added 2 paragraphs outlining the hypothesis and main contributions.

Does the title clearly reflect the contents of the paper and is it informative? The authors may consider changing the title e.g. to "Scaling effects of rigid kite ground generation airborne wind energy".

- Changed the title

3 Specific comments

Figure 3 Do these curves originate from CFDs or wind tunnel tests? From the text it sounds like the characteristic is constructed/guessed "by hand" (also indicated by the unrealistically high negative lift coefficients). – It is important to have solid aerodynamic characteristics as the sensitivity of those on the power/energy/economics is high. If the curves in Fig. 3 are polynomial simplifications based on CFDs/wind tunnel data, please plot that original data also into the graphs.

  - Clarified in text: identified in AVL CFD analyses by Ampyx Power and during untethered test flights.

Line 230 Angle of attack and thus lift coefficient seems to increase with the wind speed. This is unexpected to me. I'd rather expect the either the exact opposite to limit loads at high wind, or that the angle of attack remains mainly constant for all wind speeds during reel-out. Can you explain why the lift is changed so much? Can you also plot the apparent airspeed of the aircraft?

  - Replaced the figure with an updated version

- Reran the optimization and rewrote the plotting code. The results now make more sense, with angle of attack decreasing with wind speed to offset the increased apparent wind speed to stay within the tether force constraint.

Line 259 Weight is neglected $\rightarrow$ please clarify; the text before explains how it is accounted for

- This section has been removed in response to a request by a different reviewer.

Table 1 Where does the value for d_{tether} originate from? Should it not be left to the optimizer to find the optimal value (given the constraint that a lower tether diameter limits F_{tether}^{max})? Also, it could have been left to the optimizer to find the optimal rated wind speed.

- The optimizer is capable of finding the optimal tether diameter. However, not constraining the tether diameter will result in varying tether diameters and therefore maximum power with wind speed.
- Instead, we chose to investigate fixed AWES designs at various wind speeds, mimicking their real-world implementation.
- Yes, implementing an additional optimizer wrapped around the awebox is possible and mentioned in the future works section of the paper. One could, for example, optimize AWES for AEP or LCOE which would result in an optimal wing span and tether diameter. Another approach could be to implement the awebox into a design optimization framework to optimize aircraft design parameters. However, this was not part of this investigation and would require considerable more work accompanied by drastically increased computational cost.

Line 347 This is likely caused by outliers, or wind velocity profile specific local minima $\rightarrow$ In the paper, this is often said. How much trust can a reader give to the results, not knowing if it is a local or global minimum? (Would it be worth using simulation models and algorithms which can find the global optimum like swarm-optimization algorithms?)

- I understand the sentiment and the agree that a lot more can be done. The utilized algorithm only guarantees local minima of a highly complex problem, which should be transparently communicated.
- Determining the global optimum would also drastically increase the computational cost as it would have to be adjusted for each of the 6 designs, 3 weights, 30 wind conditions, two locations and two sets of aerodynamic coefficients. Even more computational cost if aircraft design and tether diameter would be varied to otimize AEP or LCOE.
- Therefore, a decision was made to limit the scope of this investigation on a large, but manageable amount of designs and wind conditions.
- With respect to the AEP of $A_{aircraft} = 150m^2$:
  * AEP tries to represent the power as well as the the annual wind conditions which are (somewhat) arbitrarily chosen from 10 clusters. The particular shape of that wind profile together with the complex model and optimization problem affect the total AEP.
  * Figure **??** and **??**, which are also shown in the appendix of the paper and referenced in the text, show the particular power curves (top) that were used to calculate AEP.
  * Particularly, for $A_{wing} = 150m^2$ you can see how local minima, mall decreases in power at frequent wind conditions, affect the AEP calculation.
  * Filtering out these power dips would likely solve this particular issue, but we chose to keep them in to not distort the actual results.

Line 452 However, operating heights beyond 500 m are rare and mostly occur as the system de-powers above rated wind speed to stay within tether force and flight speed

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Discussion paper

constraints. → Is it possible and meaningful to keep the maximum tether length and operating altitude below those values to reduce costs and permitting burdens?

- Yes, this is a good point and it makes sense. I included it in the conclusion

4 Minors

Line 12 we estimate a minimum average cycle-average lift to weight ratio → we estimate a minimum cycle-average lift to weight ratio (?)

- implemented and rewritten

Line 21 This study focuses on the two-phase, ground-generation concept → You might consider a full stop there and delete everything until end of line 25. No need to list (apparent) drawbacks of drag power.

- Sentences removed

Line 35 Re-power decommissioned offshore wind farms or deploy floating platforms → is this correct? source?

- Added reference

Line 66 for for

- implemented

Line 135 If the coefficients are meant not for the 2D airfoil, you may consider using capital letter C instead of lower case c. Note that C_L/C_D and C_L^3/C_D^2 has only a meaning for untethered flight or if C_D is for aircraft+tether

- Replaced with capital C to clarify that these are aerodynamic coefficients for the entire aircraft.

Line 165 to reduce the mechanical wing load → to limit ... (question: why not imposing a constraint on the wing loading directly instead?)

- removed sentence and flight speed constraint, because redundant with tether force constraint

Line 168 but implemented as tether speed, acceleration constraints → but implemented as tether speed and acceleration constraints (?)

- implemented

Line 187 Results → Results and Discussion (?)

- implemented

Line 200 However, ... → please double-check language

- rewrote section

Line 202 Consider replacing the phrase "It is striking"

- replaced

Line 204 with in → within (?)

- implemented

Line 222 it's → its (double-check entire paper for this)

- implemented

Line 237 in higher drag losses and → in higher drag losses or

– implemented

Line 237 the cosine loss due elevation angle is not caused by gravity (remove "gravity-caused")

– implemented

Line 265 what is meant by "maximum cycle-average loads"? $\rightarrow$ maximum load during a cycle?

– removed sub-section

Line 292 "only cut-in wind speed" seems lost

– removed

Line 335 lead result

– removed 'lead'

Line 359 Determining ... determined

– removed 'Determining'

Line 370 power only scales with the wing area (F_{lift} b^2) $\rightarrow$ note that the tether diameter and thus tether drag scale slower which is why power should scale faster than with b^2.

– implemented

Line 427 sim $\rightarrow$ \sim

– implemented

Line 457 a elliptical lift distribution $\rightarrow$ an elliptical lift distribution

- implemented

Line 471 do can not produce

- fixed

Line 495 offshore AWES are not particularly beneficial relative to conventional wind, given the generally lower sheer offshore → Note that this is just another confirmation of the fact, that AWES advantage (at least for this concept), in particularly offshore, lies not in higher altitudes but reduced building material and associated benefits (transport etc.).

- implemented